ROBOTIC TELESCOPES AND NETWORKS: NEW TOOLS FOR EDUCATION AND SCIENCE

François R. QUERCI and Monique QUERCI
Observatoire Midi-Pyrénées, 14 Avenue Edouard Belin, 31400 Toulouse, France
e-mail: querci@obs-mip.fr

Abstract. Nowadays many telescopes around the world are automated and some networks of robotic telescopes are active or planned. Such equipment could be used for the training of students and for science in the Universities of DCs and of new astronomical countries, by sending them observational data *via* Internet or through remotely controlled telescope. It seems that it is the time to open up for discussion with UN and ESA organizations and also with IAU, how to implement links between robotic telescopes and such Universities applying for collaborations. Many scientific fields could thus be accessible to them, for example on stellar variability, near-earth object follow-up, γ-ray burst counterpart tracking, and so on.

Keywords: robotic telescopes, automated telescopes, remote observing, networks, education, photometry, CCD imaging, spectroscopy, asteroseismology, stellar variability, NEOs follow-up, GRB object monitoring

1. Introduction

The telescopes about which we talk, are mainly small-sized telescopes from 50-cm to 1-m diameters and middle-sized telescopes of the 1-m to 3-m class. A lot of science can be done with them. Astrophysics of the next century do not need only large telescopes of the 10-m to 40-m class, but also small ones which can open up new fields of research also. Today, our knowledge is still limited on subjects such as: - stellar variability (all stars are variable) studied through asterosismology which determines the various pulsation modes of the stellar interior, and through the modeling of stellar photospheres and external envelopes which has to take into account the eventual presence of spots, disks, jets, etc., - visible counterparts of γ-ray bursts (hereafter GRBs), - near-earth objects (hereafter NEOs) (see the japanese proposal in these proceedings), - supernova (it exists supernova search programs), - planets around stars (the first exoplanets were discovered with the 1.93-cm telescope in *Haute-Provence Observatory*, France).

Many of these scientific objectives imply to observe the same stellar objects during a long time, before they can be reached.

Many tools were, are, and will be developed for such researches. As an example about the stellar variability, in the past the multi-site and multi-wavelength observing campaigns with current telescopes were

developed for studying short-period variables such as the white dwarfs and the δ Scuti stars, since such campaigns could be organized only during a few weeks by year (*e.g.* as discussed in Querci and Querci, 1998a). Today, dedicated automated telescopes (AT) or robotic telescopes (RT), or networks of them, as well as networks of interferometers are a powerful tool for the follow-up observations of all the types of variables. Tomorrow, orbiting telescopes such as WSO (World Space Obs.) will challenge the networks.

Coming back to the observing campaigns with current telescopes, and to AT, RT and Networks of them, the latter seem the best adapted equipment to the DCs and the new astrophysical countries at a very low cost relatively to the benefit they could gain, for investigating new fields of research, for example on object variability, and/or for preparing future observations with the large telescopes.

2. Overview of the equipment

Firstly, let us recall some definitions:
- **Automated telescopes (AT)** follow a prescribed set of procedures and perform the indicated tasks.
- **Robotic (or automatic) telescopes (RT)** operate without human help at all. They offer a remote operation capability, however a **fully robotic telescope** is not supervised either locally or remotely during its routine operation. Improvements are required to work in hostile environments.
- **Networks of RT** are under the control of a main station. The data are *immediately* sent to all the members of the network.
The main station has in charge the control of the quality of the data and also the control of the data archives accessible via Internet.
The scientific programmes are defined by an international scientific board.

The equipment is or will be used: - in a local manual mode for the student training, - in a remote control mode via Internet for the student training and for research, - and, of course, in a complete automated mode for research.

It includes:
- a weather station with sensors for clouds, rain, humidity, snow, sand wind, high speed wind, interfaced to a site-control computer which drives the dome and initializes the telescope processing.

- an automated dome (a dome protects the equipment from humidity during the observations),
- or a roll-off roof which, once opened, allows fast movements of the telescope necessary in the GRB counterpart tracking and the monitoring of a great number of objects per night (in some sites, when the telescope is inactive, an impenetrable dome or roof is needed because of the sand winds),
- the telescope,
- and its own equipment, *i.e.* a CCD photometer and a spectrograph, and a polarimeter. More specifically: - a large-field camera to search for supernovae, optical counterparts of GRBs and NEOs, - and/or a middle-sized field camera for variable star studies, - a spectrograph with optical fibers (at low and/or high resolutions).
- a computer to drive the dome, the telescope and its equipment to perform the observations by taking into account the local and sky constraints.
- a disk storage for recording the scientific observations and their technical parameters.
- an Internet server to receive the observing instruction requests and to transmit the resulting data and the technical parameters.
- facilities for reducing the data on line for the network members.

An example of operational automatic telescopes equipped with automated photometers for high-precision photometry is described by Henry (1999).

3. AT, RT and Networks around the world for research and/or education

At the international workshop on APTs held in 1986 as the Seventh Annual Fairborn IAPPP Symposium (*Automatic Photoelectric Telescopes*, eds. D.S. Hall, R.M. Genet, and B.L. Thurston, The Fairborn Press), the powerful capability of making differential photoelectric photometry automatically was highlighted. Then, year after year, meetings on the automated astronomy showed how a lot of research programmes are best achieved through this technique. The usefulness of APTs for education is also unquestionable.
The world-wide view of the existing and planned robotic, automated, and remote-controlled telescopes appears today useful: - to help to link such world-wide telescopes in multi-longitude networks for future cooperations in time series studies or in the gathering of time

critical data, - to inform the DCs, - and to incite them to participate. Also such networks are a valuable tool for education in allowing students to contribute to current research in astronomy (*e.g.* the MicroObservatory, see §3.2).

We endeavour to update and to complete some source lists that can be found at the following web site addresses:
http://www.telescope.org/rti/automated.html (Mark Cox),
http://gamma.bu.edu/atn/auto_tel.html (John Mattox),
http://alpha.uni-sw.gwdg.de/hessman/MONET/links.html (F.V. Hessman).
As the AT and RT have an ever-increasing success, the following lists are certainly not exhaustive.

3.1. Telescopes dedied mainly to research

The classification is in order of countries by longitude from West to East, and by telescope sites. We also note the institution(s) in charge of the telescopes and we give some paper references and/or PI. For each individual research telescope, are given: the diameter in cm, its status (operational: O, under construction: C, in project, in test), the main research topics, educational use if specially mentioned. A special list in the next paragraph gives the telescopes dedied to education.

Canada

• Kingston (Ontario) - Queens Univ. Astronomy Research Group
- AT; 40; C; for education and research

USA

• Buckley (Washington), Torus Observatory
- computer-controlled; 40; O; asteroid astrometry for the MPC, searching for new asteroids; will be used for education for the surrounding colleges and universities; PI: Rich Williams

• Orcas (Washington), Heron Cove Obs. / Jaimeson Science and Engineering
- computer-controlled; 50; O; asteroid searches and follow-ups

• Lick Observatory, California/ UC Berkeley Astronomy Dept.
- KAIT (The Katzman Automatic Imaging Telescope); Richmond et al., 1993, 1999
76; O; search for supernovae, comets

• Mt. Laguna / San Diego State University, California
- automatic; 50; in project; a GNAT (Global Network of Astronomical Telescopes, see §3.4) node

• Fairborn Observatory (Arizona), a foundation that operates auto-

matic telescopes (presently 13 ones from 25 to 81 cm) for various institutions among them:

Tennessee State University:

- APTs (Automatic Photoelectric Telescopes); Pioneer: Louis J. Boyd; Henry, 1995, 1999

75 & 80; O; sun-like stars, extrasolar planets (joint project with Harvard-Smithsonian Center)

2 * 25; O; semi-regular variables

41; O; chromospherically active stars (joint project with Vanderbilt University)

3 * 80; C

- AIT (Automated CCD Imaging Telescope)

61; C; web-based interface - authorized users will submit their observing requests

- AST (Automatic Spectroscopic Telescope); Eaton, 1995

206; C; wide range of projects in high-resolution echelle spectroscopy: magnetic cycles, variability, winds, pulsation in cool stars

Vienna University (Austria)

- APTs; *e.g.* Strassmeier et al., 1997a

twin 75 (Wolfgang-Amadeus); O; cool starspot monitoring, asteroseismology (δ Scuti, λ Boo stars), monitoring of AGB stars

Four College consortium (USA)

- APT, P.I.: Bob Dukes; 75; O; wide range of observing programmes: pre-main sequence variables, pulsating variables, Be stars, post AGB variables, solar proxies, high velocity stars, RS CVn stars, BY Dra variables, eclipsing binaries, etc.

• Winer Mobile Observatory (WMO), Sonoita, Arizona, provides site and maintenance services for remotely operated telescopes through cooperative agreements with other astronomical institutions of which:

- University of Iowa (Iowa Robotic Telescope Facilities: IRTF) (see §3.2)

- Washington University (St. Louis, Missouri); 50; C; joint project with the Indian Institute of Astrophysics (see India, Ladakh, below) for GRB object monitoring

• Tenagra Observatories, Sonoita, Arizona

- RT; 35; O; supernova patrol; minor planet discovery; time series studies of variable stars; also dedicated to education; contact: M. Schwartz, Cottage Drove, Oregon

- RT; 81 and 50; C

• Kitt Peak, Arizona / SARA consortium (five Universities)

- SARA Telescope, remote observing possible; Oswalt et al., 1994

90; O; Mira variables, Vega-type stars, white dwarfs, BL Lac, etc.; hosts a REU (Research Experiences for Undergraduates) program (sponsor: NSF)

• Kitt Peak, Arizona / Automatic Telescope Network (ATN)-Node
- AOK Telescope; robotic; Mattox et al., 1999
130; proposed to be a prototype ATN (see §3.4); optical counterparts of GRB; blazar monitoring (during the GLAST GR mission)
• Tucson, Arizona
- ARO (Apogee Robotic Observatory)
35; C; test bed for customers; suited for group research and education
• Tucson, Arizona / Clemson University, South Carolina / Lawrence Livermore National Laboratory (LLNL)
- Super-LOTIS (Livermore Optical Transient Imaging System)
60; C; dedicated to GRB optical counterpart search
• NF/Observatory, New Mexico / Western New Mexico Univ.
- *Automatic Radio-Linked Telescope (ARLT)*; Robotic and remote; radio-linked to Internet; Neely, 1995
44; O; BL Lac objects, asteroids, supernova search, Mira survey, etc., by CCD Imaging
• Los Alamos National Laboratory, New Mexico
- ROTSE (Robotic Optical Transient Source Experiment); PI: C.W. Akerlof, Univ. of Michigan
- ROTSE-I telephoto camera (array of four electonic cameras on an equatorial platform); automated pointing system; O
- ROTSE-II telescope: robotic twin 45 cm telescopes; O
search for optical counterparts of GRB in coordination with BATSE; comets, quasars
• University of Iowa
- One-Meter ATF - Educational Observatory (EO institute); Robotic and remote; 100; C; CCD Imaging and Spectroscopy; deep galaxy imaging survey; dwarf-satellite galaxy population; Embedded Infrared Sources in the Galactic Plane; participation in the WET observations; also for education, see below)
• Hanna City Robotic Telescope (Illinois)
- Remote and Robotic; Gunn and Lamb, 1997; 21; O; CCD photometry of stars; light curves of eclipsing binary stars
• Goethe Link Observatories (Morgan-Monroe Station) / Indiana University, Bloomington
- AT named *RoboScope*; Honeycutt et al., 1989; 1994
40; O; long-term monitoring of cataclysmic variable stars and related objects
- AT named *SpectraBot* for both CCD imaging and spectroscopy; Honeycutt et al., 1993, 1998
125; C; long-term monitoring of time-variable sources
• University of Michigan

- ROTSE-II telescope (see Los Alamos Nat. Obs., New Mexico); C

• Nassau Astronomical Station, Ohio / Case Western Reserve Univ. (Ohio)

- RT for both CCD imaging and spectrography; contact: Earle Luck, Observatory's Director

90; C; will be a partner in the *Hands-On Universe* program (see §3.2)

Colombia

• Bogota - Universidad Sergio Arboleda

- AT; 40; C; for education and research

Canary Islands (Spain)

• La Palma / Liverpool John Moores University

- RT; Steele, 1999

200; C; long-term monitoring; rapid response; ground-based supports simultaneously to satellite observations; small-scale surveys (see the Web site of ROBONET §3.4); some school children will also be able to use the telescope to study the universe.

• La Palma (Roque de los Muchachos) / Copenhagen Univ.(Denmark), RGO (Cambridge, U.K.)

- CAMC (Carlsberg Automatic Meridien Circle); O; contact: L.V. Morrison, RGO

- Danish Strömgren Automatic Telescope; 50; O; contact: J. Viggo Clausen

• Tenerife (The Teide Observatory) / Bradford University (U.K.)

- RT; Director: J. Baruch

30; O; devoted to search for the counterparts to gamma burster events detected by the Compton Gamma Ray Observatory satellite; used by school pupils in the classroom from U.K. (also experimented from Tokyo)

France

• ROSACE Automated Telescope, CNES-Toulouse, France

- RT; 50; in test; satellite tracking; contact: E. Cazala -Hourcade

• Observatoire de la Côte d'Azur (Plateau du Calern) / Centre d'Etude Spatiale des Rayonnements (CESR), Toulouse

- AT (TAROT: Rapid Action Telescope for Transient Objects); Contact: M. Boer

25; under test; detection of optical transients from cosmic GRB

South Africa

• Sutherland / South African Astronomical Observatory (SAAO)

- RT; 75; C

Italia

• Mt. Etna / Catania Astrophysical Obs.

- APT; M. Rodono, Director - *e.g.* Strassmeier et al., 1997b

80; O; RS CVn, BY Dra type stars; flare stars; chemically peculiar A-type stars; cepheids; short-period variables

• Perugia Astronomical Observatory

- AIT (Automatic Imaging Telescope); Tosti et al., 1996a

40; O; variability of objects brightest than 17 mag. on V; monitoring of blazars

- ORIT (Optical Robotic Imaging Telescope); Tosti et al., 1998

80; O; monotoring of variable sources

Slovenia

• Crni Vrh Observatory / University of Ljubljana

- AT; Mikuz and Dintinjana, 1994

36; O; photometry of comets; follow-up astrometric observations of NEOs and comets, of main-belt asteroids; variable stars; newly discovered Novae and Supernovae; part of telescope observing time is for advanced student observing programs.

Czech Republic

• Ondrejov Robotic Telescope

- RT; *e.g.* Soldan and Nemcek, 1996

25; O; follow-up observations of GRB optical-counterparts; optical SETI observations (joint project with Columbus Optical SETI Obs.); ground-based support of satellite observations

Bulgaria

• Belogradchik Observatory

- RT; Antov and Konstantinova, 1995

60; O; CCD photometry of fast flare events, of flare-like events on evolved stars (red giants), of flickering of cataclysmic and symbiotic variables, and of comets

Russia

• Zvenigorod Observatory, Moscow

- will automate their large telescope and add it to the TIE (Telescopes in Education) system (see §3.2)

India

• Inter-University Centre for Astron. Astrophys. in Pune

Almost identical telescope to the Liverpool Telescope (see Canary Islands, La Palma)

- RT; 200; in project; for use of the astronomical community from all Indian universities

• Mt. Saraswati, Ladakh, state of Jammu and Kashmir / Indian Institute of Astrophysics (Bangalore)

- AT; 50; C; joint project with Washington Univ. (St. Louis, Missouri); to monitor GRB objects

Korea

• Yonsei University, Seoul /Center for Space Astrophys. and Dept. of

Astronomy
- RT; 50; O; TAOS (Taiwan-America Occultation Survey) project

New Zealand

• Auckland Robotic Observatory; 28; C; variable stars

China

• Hong Kong / Chinese University
- automated; 40; C; for education and research programs

Taiwan

• Taipei / Dept. of Earth Sciences, National Taiwan Normal Univ.
- automated; 40; C; for education and research programs

• Yu-Shan (Jade Mountain) National Park / National Central Univ. (Inst. of Astron.) / Academia Sinica (Inst. of Earth Sciences and Inst. of Astron. Astrophys.) / LLNL (California, USA)
- robotic; 3 * 50; C; TAOS project

Japan

• Bisei Town, Japan Space Forum (JSF) project
- automated telescopes: 100 and 50 to be networked; C; detection of space debris, orbits of NEOs

Antarctica Plateau

• Dome Concordia/Perugia Astronomical Observatory (Italia)
- IRAIT (Italian Robotic Antarctic Infrared Telescope); Tosti et al., 1996b

80 plus IR camera (8-27 μm or 8-40 μm); in project; long-term monitoring of variable sources; surveys of selected sky fields at 10 μm and 20 μm; dusty environment in the Galaxy; old and young populations in nearby Galaxies

3.2. Telescopes dedied to Education

• Hawaii (Honolulu)
- The LCC Observatory; computer operated telescopes in the 20-30 cm range for high school student projects; CCD imaging systems; variability, comets; contact: Fritz Osell

• UC Santa Barbara (California)
- ROT (Remotely Operated Telescope), heart of RAAP (Remote Access Astronomy Project); contact: Philip Lubin

35.6; O; high schools and junior colleges

• Telescopes in Education (TIE) program
- remotely controlled telescope at Mount Wilson Observatory (California) used by students around the world; J. Cohen, 1997

60; O; widely used by schools and individuals

35; O; available only to select users

A **TIE network** of world-wide automated telescopes is in project; also TIE will restore and automate research telescopes which will then be added to its network

• Hands-ON Universe (HOU)

- research programs for high and middle school students;

uses LBNL (Lawrence Berkeley Nat. Obs., California) Nearly Supernova Search Telescope; 76; to be extended to other telescopes to form a network of automated telescopes for education (*e.g.* Nassau Station, see above)

• Winer Mobile Observatory (WMO), Sonoita, Arizona/ Iowa Robotic Telescope Facilities: IRTF

- RT (Iowa Robotic Observatory: IRO); 50; O; primary use is for teaching and research in undergraduate laboratories at Iowa universities

• University of Iowa (Iowa Robotic Telescope Facilities: IRTF)

- ATF (Automated Telescope Facility); 18 cm refractor; O; primary use is for teaching and research in undergraduate laboratories at Iowa universities

• Highland Road Park Observatory / Louisiana State Univ. (LSU) (Baton Rouge Obs.)

- Remote, accessed over the Internet; connected to the LSU Astronomy Teaching Laboratory to train teachers and students; 50; C

• University of Wisconsin, Oshkosh

- *Stardial Number 2*, see Univ. of Illinois below; C

• University of Illinois, Urbana-Champaign

- *Stardial*, an Instructional Tool: it is an autonomous astronomical camera for providing real-time images of the night sky for students to access and study via the WWW; O; Dietz, Heasley and McCullough, 1999

• CASS (Center for Automated Space Science)/NASA Univ. Research Center, Maryland

- students have opportunities to participate in automated remote observing programs with ground-based telescopes and NASA missions

• MicroObservatory / Harvard-Smithsonian Center for Astrophysics, New Jersey

- a **network** of five automated telescopes controlled over the Internet; for students and teachers nation wide; PIs: O. Gingerich and Ph. Sadler

• Bradford Robotic Telescope Observatory on Oxenhope moor

- Robotic and Remote; Baruch, 1993; Cox and Baruch, 1994;

46; O; the telescope uses a WWW gateway to provide access for schools, amateurs and professionals. Anyone on the Internet can register and ask the telescope to look at anything in the northern night sky.

Students are encouraged to submit class projects.

Also Bradford Univ. has a 30-cm RT in Canary Islands, Tenerife (see §3.1)

• Oxie, Sweden, Tycho Brahe Observatory

- new telescope system with complete remote-control ability; under construction; will offer real time remote observing for students and teachers nationwide

3.3. Remote observing on research classic telescopes

Remote observing is an observing mode where the astronomer is not physically present at or near the telescope (see for comments, Zulstra et al., 1997). Robotic telescopes are a related implementation.

Remote observing is clearly advantageous for the many world-class large and giant telescopes which are in high-altitude observatories. There, astronomers very often feel uncomfortable and their observing efficiency is affected. Also, this observing mode is appropriate when the home institution is far from the observing site, saving astronomer's travel and time, or when observing runs are short. Moreover, an advantage is that every member of a scientific cooperation can share the various duties related to the observations and students can more easily been included in an observing run. In fact, the imperative requirement for remote observing is a fast data transfer system between the site and the home. We quote:

• Mauna Kea summit, Hawaii (US)

- UKIRT (United Kingdom Infrared Telescope)

3.80 m; (Economou et al., 1996)

- Subaru Telescope Project (Nat. Astron. Obs. of Japan)

8.3-m optical-infrared telescope; in test; will be controlled remotely from anywhere else in the world

- W.M. Keck Observatory

twin 10-meter optical/infrared telescopes; pioneering the routine use of remote observing: operational from Waimea, in progress from mainland US (waiting for a reliable, separate, dedicated link; experimented from California); Conrad et al., 1997; Kibrick, 1998

• Mauna Kea summit, Hawaii (US) and Cerro Pachon (Chile)

- Gemini project: two 8-m telescopes, one in Hawaii, one in Chile; will support remote observing mode

• Hat Creek, California (US) / BIMA (Berkeley-Illinois-Maryland Association)

- millimeter wave interferometer: nine 6-m diameter antennas (Hoffman et al., 1996)

• Mt. Hopkins, F.L. Whipple Obs., Tucson, Arizona (US) / Multiple Mirror Telescope (MMT) Observatory (CfA/OIR)

- conversion of the MMT in a 6.5-m telescope; C; remote MMT observing was possible

• Kitt Peak, Tucson, Arizona (US) / NRAO

- 12 m; remotely observing capabilities are being extended to a wide audience

• Apache Point Observatory, Sunspot, New Mexico (US) / Astrophysical Research Consortium (ARC) (five Universities)

- 3.50 m; remote observing possible from ARC member campuses through the Internet

• Moore Observatory, Kentucky (US) / Univ. of Louisville

- the Solar Flare Monitor is remotely operated; a remote observing facility is under development on a 40-cm telescope

• La Silla (Chile) / ESO (European Southern Observatory)

- 1.4-m CAT (Coudé Auxiliary Telescope) and 3.58-m NTT (New Technology Telescope); remote observing offered from Garching (Germany) (Zulstra et al., 1997)

• Pico Veleta, Sierra Nevada, Granada (Spain)

- IRAM (Institut de RadioAstronomie Millimétrique)

30 m; remote observing at Pico Veleta possible from IRAM Grenoble (France) and from the IRAM Granada office

• South Pole / CARA (Center for Astrophysical Research in Antarctica)

- SPARO (Submillimeter Polarimeter for Antarctic Remote Observing) operates on the Viper 2-m telescope

3.4. Networks

Since more than a decade, the idea of networks of robotic telescopes appeared for example through the GNAT (Global Network of Automatic Telescopes) and the NORT (Network of Oriental Robotic Telescopes) initially called ORT Network. Unfortunately, for various reasons from ventures into manufacturing robotic telescopes for GNAT to a disinterestedness of the french authorities for automation in the case of NORT, the building of these earliest network of robotic telescopes for research and education has not yet come into effect. Today, it is an idea worldwide accepted, and the proposal of networks, either local or global, is growing. Comments on *Networks of Automated Telescopes Today* can be found in Williams (1999). Here are the networks of robotic telescopes of which we have had knowledge.

• **ATN** (The Automatic Telescope Network) (Mattox et al., 1999);

http://gamma.bu.edu/atn

- CCD imaging; 8 planned telescopes of 1.3-2.0-m diameter; GRB studies; variable stars; asteroseismology, etc.; partner in *Hands-On Universe Project* (see §3.2); will take over from the network, the Whole Earth Blazar (WEB) Telescope

• **EON** (European Observational Network) for Observations of GRB and optically violent AGNs; contact: R. Hudec, Astronomical Inst. Ondrejov, Czech Republic; *http://altamira.asu.cas.cz/eon/*

• **GCN** (The Gamma-ray burst Coordinates Network) incorporated to BACODINE (The BATSE COordinates DIstribution NEtwork); contact: S. Barthelmy, Goddard Space Flight Center;
http://gcn.gsfc.nasa.gov/gcn/

• **GNAT** (Global Network of Astronomical Telescopes) (Crawford, 1997); *http://www.gnat.org/∼ida/gnat/*)

- Imaging and photometry; a 50-cm automatic telescope prototype is being tested; incorporates ATIS communication system (see §3.5); gotten data are already used by graduate students at Colorado State Univ. for their research projects

• **GONG** (the Global Oscillation Network Group); NOAO, Tucson, Arizona; *http://www.gong.noao.edu/*

- six-station network around the Earth (Big Bear, Learmonth, Udaipur, Teide, Cerro Tololo, Mauna Loa) for a detailed study of solar internal structure through heliosismology

• **LBI and VLBI networks**

- Centimetre wavelength Networks: EVN (European VLBI Network), VLBA (US), Merlin, JNET (Japanese VLBI network), Australian VLBI array, APT (Asia Pacific Telescope network)

- Millimetre Wavelength Network: mm-VLBI array (M.I.T)

• **NORT** (Network of Oriental Robotic Telescopes); Querci and Querci, 1998a,b; *http://www.saao.ac.za/∼wgssa/as2/nort.html*

- project selected by COPUOS, United Nations, Dec. 1996; 6-8 stations along tropic of Cancer from Morocco to China with 1.50-m RT; complementary to other networks; CCD photometry, spectroscopy; variable stars, asteroseismology, etc.

• **Robonet** A Global Network of six 2m Robotic Telescopes; contact: Ian Halliday, Wiltshire, U.K.

- in project; 3 northern and 3 southern telescopes at widely spaced longitudes; prototype: see §3.1 Canary Islands - Liverpool John Moores Univ.; multi-wavelength time variability, targets of opportunity, etc.; *http://star-www.st-and.ac.uk/∼kdh1/jifpage.html*

• **Spaceguard Network** (Global Network for Research on Near-Earth Objects); joint project: Spaceguard Foundation / European Space Agency; *http://www.crl.go.jp/ka/control/asteroid/SGF*

- automated telescopes; under study

3.5. Working Groups - Softwares

Consortiums to promote access to robotic telescopes and to develop related softwares have been set up. Let us mention:

• **APA** (Associate Principal Astronomer) project

- it performs a number of functions in support of a human PA in planning, scheduling, and control for automatic telescopes; *http://ic-www.arc.nasa.gov/ic/projects/xfr/*

• **AstroNet**; S. Godlin and S. Chakrabarti, 1994

- " A toolset for simultaneous, multisite, remote observations of astronomical objects"; project that will provide an international network of observatories and space-based instruments

• **ATIS** (Automatic Telescope Instruction Set); Henry, 1996

- is a language to program automatic photoelectric telescopes; it is being improved to include spectroscopy, telescope networking, and telescope scheduling commands

• **ISTeC** (International Small Telescope Cooperative)

- planet-wide organization to promote access to small (<3 m) telescopes for research and education, and to coordinate multi-site campaigns; *http://astro.fit.edu/istec*

• **IWGAT** (The International Working Group on Automatic Telescopes)

- is developing standards for the operation of a network of diverse robotic telescopes to promote the development of robotic telescope software for general use (see ATN in §3.4)

4. Where can we implement more such equipment?

An observing site research has to be done worldwide to find new sites for the proposed networks. For example as described in Querci and Querci (1998c, 1999), it appears that many such sites are in Developing Countries on the basis of preliminary results on the mean annual nebulosity from Morocco to China obtained in the frame of the NORT project.

The various steps in such a research are: - to prospect for **high mountains** in semi-desertic climate (the site has to be above the atmospheric reversing layer), - to pre-select sites through **meteorological satellites** data, - to analyse the **anti-correlated airstreams** for avoiding

several sites on the same airstream, - to proceed to measurements by *in situ* **seeing-monitor** or **grating scale monitoring** on the pre-selected mountains, through campaigns done during various seasons on a few years.
It could be a way to introduce Astronomy and Space Science in DCs.

5. How to contribute to the introduction of Astronomy and Astrophysics, and Space Science in the DCs education cursus?

Preliminary to going into scientific projects with robotic telescopes, some education and training are necessary to achieve them. Let us give examples.
• Basic courses, conferences and bibliography in Astrophysics are found on several Web sites (*e.g.* see also §3.2).
• Summer Schools are opened to the DC students to introduce them to the basis in Astrophysics or to improve their knowledge, and to allow them to practise a telescope often for the first time. Among them:
- the IAU/UNESCO International School for Young Astronomers (ISYA) which is scheduled each two years since 1990,
- the WGSSA-UN (Working Group for the Spatial Sciences in Africa in behalf of UN) Schools:- in South African Astrophysical Observatory for anglophone students, - in Observatoire de Haute-Provence, south of France, for francophone students.
• A Newsletter within the framework of UN, dedied to Africa, *African Skies/Cieux Africains* (ed.: F.R. Querci; co-eds.: M. Querci and P. Martinez), presents basic papers in astrophysics and news on equipment and research from the various observatories and laboratories in Africa. It is freely distributed by UN and also hosted by the WGSSA Web page at: *http://www.saao.ac.za/∼ wgssa/*.
• A Newsletter within the framework of the Italian Astronomical Society presents general cultural and didactic astronomical informations in arabic language (ed.: F. Bònoli, Arcetri Observatory).

For example, to understand the stellar variability, **non-stop observations** and hydrodynamical modelling have to be handled as shown by the NASA/CNRS Monograph Series on *Nonthermal Phenomena in Stellar Atmospheres* (eds. Stuart Jordan and Richard Thomas), for the various types of variable stars in the H-R diagram. **Indeed, the study of these objects does not need very large telescopes. Diameters between 50 cm and 2.00 m for photometry and**

spectroscopy respectively, are appropriate. The non-stop observations are only possible with Networks of telescopes.
Such a subject of research could be an introduction to contemporary Astrophysics for the DCs.

6. How to convince the national authorities to introduce Astronomy and Astrophysics, and Space Science in the DCs education cursus?

We, astrophysicists, cannot directly act on the objects that we study, as the chemist or the physicist does in his laboratory. First and foremost we are observers. So, to try to understand the Universe that we observe, we need to develop a lot of technologies in collaboration with other scientists and engineers: mathematicians, physicists, electronics engineers, opticians, etc. Industrial challenges are issued, first point able to arouse the national authorities's interest. In return, the technologies developed in our observatories in collaboration with companies can be used for the benefit of other sciences. Let us give an example which we have followed closely.
The first CCD camera were developed by army and by astronomers in various countries. In Toulouse, in the early 80s the Observatory and the Faculty of Medecine cooperated for the study of the coroïde cancer with CCDs. In mid-80s, in collaboration with the hospital of our University, our observatory developed an experimental endoscope with a CCD camera on its top to look inside the human body. Moreover, the CCD image data processing is adapted to an early identification of pathologies, becoming much more quantitative and accurate.

7. Concluding questions

• How would we coordinate the efforts made:
- inside a new astronomical country?
- inside a given region (Western Asia, Africa, etc.)?
• How would we open the present AT, RT, and Networks to other new scientific groups, at least the data banks of such equipment?
• How to prepare standard training?
• How would we help out the Faculty Professors of the new astronomical countries for their first courses in Astronomy, for their training, for reducing the data, etc.?
• How would we help the colleagues of these countries when they plan

to develop their own equipment?
• How the *Northern* observatories should help out in the achievement of the development of **astrophysical laboratories** in DCs?
• How would we convince the national authorities of these countries to introduce Astronomy & Astrophysics and Space Sciences in their Universities?
• How would we draw up an inventory of the needs with the help of: - various laboratories around the World (having robotic equipment) where DCs students are preparing PhD thesis, - IAU, - UN Outer Space Office?

In the majority of cases an adapted answer has to be found. It has to be proposed for the benefit of science and humanity.

References

Antov, A., Konstantinova, R. 1995, in *Robotic Observatories*, ed. Michael F. Bode (John Wiley and Sons / Praxis Publishing, Chichester), p.69

Baruch, J.E.F. 1993, in *Vistas in Astronomy*, vol. 35, p. 399

Cohen, J. 1997, *Students as Astronomers: Gaining new vision with the Mount Wilson telescope*, INSIGHTS, Issue 2, May 1997 (pub. by NASA's HPCC Program office)

Conrad, A.R., Gathright, J., Kibrick, R.I. 1997, in Proc. SPIE Telescope Control II Symposium, July 27, 1997, ed. H. Lewis, p. 99

Cox, M.J., Baruch, J.E.F. 1994, in Proc. *Second International Conference of the World-Wide Web*, October 17-20th 1994, Chicago

Crawford, D.L. 1997, IAU August 1997 GA in Kyoto (Japan), Joint Discussion 20, in Highlights of Astronomy (Kluwer)

Dietz, R.D., Heasley, J.N., McCullough, P.R. 1999, 193rd Meeting of the American Astron. Soc., Austin, Texas, January 1999

Eaton, J.A. 1995, in *Robotic Telescopes: Current Capabilities, Present Developments, and Future Prospects for Automated Astronomy*, ASP Conf. Ser., eds. G.W. Henry and J.A. Eaton, Vol. 79, 226

Economou, F., Bridger, A., Daly, P.N., Wright, S. 1996, in *Astronomical Data Analysis Software and Systems V*, eds. G.H. Jacoby and J. Barnes, ASP Conf. Series, vol. 101

Godlin, S., Chakrabarti, S. 1994, NASA Science Information Systems Newletter, Issue 34

Gunn, J.B., Lamb, Ch. F. 1997, AAS meeting

Henry, G.W. 1995, in *Robotic Telescopes: Current Capabilities, Present Developments, and Future Prospects for Automated Astronomy*, ASP Conf. Series, eds. G.W. Henry and J.A. Eaton, Vol. 79, 37; 44

Henry, G.W. 1996, in *New Observing Modes for the Next Century*, eds. T.A. Boronson, J.K. Davies, and E.I. Robson, ASP Conf. Series, Vol. 87

Henry, G.W. 1999, P.A.S.P., to be published

Hoffman, W., Hudson, J., Sharpe, R.K., Grossman, A.W., Morgan, J.A., Teuben, P.J. 1996, *Astronomical Data Analysis Software and Systems V*, eds. G.H. Jacoby and J. Barnes, ASP Conf. Series, vol. 101

Honeycutt, K., Adams, B., Grabhorn, R., Turner, G., White, J., Vesper, D. 1989, in *Remote Access Automatic Telescopes*, eds. D.S. Hayes and R.M. Genet (Mesa, Fairborn Press), 105

Honeycutt, R.K., Turner, G.W., Vesper, D.N., Robertson, J.W., White, J.C. 1993, P.A.S.P., 105, 426

Honeycutt, R.K., Adams, B.R., Swearingen, D.J., Kopp, W.R. 1994, P.A.S.P., 106, 670

Honeycutt, R.K., Robertson, J.W., Pier, J.R. 1998, in Proc SPIE Conf. on *Optical Astronomical Instrumentation*, Vol. 3355, p. 696

Kibrick, R.I., Conrad, A.R., Perala, A. 1998, in ACM Interactions, vol.5, $n^{\circ}3$, p.32

Mattox, J., Wagner, S., Tosti, G., Honeycutt, K. 1999, Symposium on *Research Amateur Astronomy in the VLT Era*, Garching, Germany, August 7-13, 1999

Mikuz, H., Dintinjana, B. 1994, International Comet Quaterly (ICQ), ed. D.W.E. Green, October 1994

Neely, A.W. 1995, poster at the AAS Meeting, January 1995

Oswalt, T.D. and 15 co-authors 1994, *Long-Distance Astronomy: The SARA 0.9-m Telescope at Kitt Peak*, BAAS, 185, 1001

Querci, F.R., Querci, M. 1998a, Astrophys. and Space Science, 258, 387

Querci, F.R., Querci, M. 1998b, in I.A.P.P.P. Communications, $n^{\circ}69$, p.6 (ed. T.D. Oswalt), from IAU Joint Discussion 20 on *Enhancing Astronomical Research and Education in Developing Countries*, at IAU GA, 1997 August 26, Kyoto (Japan)

Querci, F.R., Querci, M. 1998c, ASP Conf. Series, Vol. 139, p. 135 (eds. S. Isobe and T. Hirayama)

Querci, F.R., Querci, M. 1999, in IAU Symposium 196 *Preserving the Astronomical Sky*, held in Vienna (Austria), 12-16 July 1999, to be published in ASP Conf. Series (eds. R.J. Cohen and W.T. Sullivan)

Soldan, J., Nemcek, M. 1996, Proc. SPIE *The Search for Extraterrestrial Intelligence (SETI) in the Optical Spectrum II*, eds. S.A. Kingsley and G.A. Lemarchand, Vol.2704, p.92

Steele, I.A. 1999, *The Liverpool Robotic Telescope*, to appear in "Instrumentation at the ING: The Next Decade", New Astronomy Reviews, Elsevier Press, eds. N. Walton and S. Smart.

Strassmeier, K.G., Boyd, L.J., Epand, D.H., Granzer, Th. 1997a, P.A.S.P., 109, 697

Strassmeier, K.G., Bartus, J., Cutispoto, G., Rodono, M. 1997b, Astron. Astrophys. Suppl. Series, 125, 11

Richmond, M., Treffers, R., Filippenko, A.V. 1993, P.A.S.P, 105, 1164; 1999, Sky and Telescope, Vol.97, nber 1, January 1999, p. 26

Tosti, G., Falchetti-Frescura, A., Fiorucci, M. 1998, *BL Lac Phenomenon"* Poster Session, a Conference held 22-26 June, 1998, in Turku, Finland

Tosti, G., Pascolini, S., Fiorucci, M. 1996a, P.A.S.P., 108, 706

Tosti, G., Maffei, P., Pascolini, S., Valenziano, L., Fiorucci, M., Busso, M., Corcione, L., Persi, P., Ferrari-Toniolo, M. 1996b, Astron. Astrophys. Tr. Special Issue on JENAM-95

Williams, R.J. 1999, in Eight UN/ESA Workshop on Basic Space Science, held in Mafraq, Jordan, March 1999 (to appear in Astrophys. and Space Science, Kluwer)

Zulstra, A.A., Wallander, A., Kaper, L., Rodriguez, J.A. 1997, P.A.S.P., 109, 1256